Mineral Biomarkers in Martian Meteorite ALH84001? Kathie L. Thomas-Keprta[1], Dennis A. Bazylinski[2], Susan J. Wentworth[1], David S. McKay[3], D.C. Golden[1], Everett K. Gibson Jr.[3] and Christopher S. Romanek[4]; [1]Lockheed Martin, Mail Code C-23, NASA/JSC, Houston, TX 77058 (KThomas@Ems.Jsc.Nasa.Gov); [2]Dept. of Microbiology, Immunology, and Preventive Medicine, Iowa State University, Ames, IA 50011; [3]NASA/JSC, SN, Houston, TX 77058; [4]SREL, Drawer E, Univ. of Georgia, Aiken, SC 29802

Introduction The occurrence of fine-grained magnetite in the Fe-rich rims surrounding carbonate globules in the martian meteorite ALH84001, originally described in [1], have been proposed as fossil remains of primitive Martian organisms. Here we report observations on size and shape distributions of magnetites from ALH84001 and compare them to biogenic and inorganic magnetite crystals of terrestrial origin. While some magnetite morphology is not unequivocally diagnostic for its biogenicity such as cubodial forms of magnetite [3], which are common in inorganically-formed magnetites, other morpholgies of magnetite (parallelepiped or elongated prismatic [4] and arrowhead forms [5]) are more likely signatures of biogenic activity [2]. Some ALH84001 magnetite particles described below have unique morphology and length to width ratios that are indistinguishable from a variety of terrestrial biogenic magnetite and distinct from all known inorganic forms of magnetite.

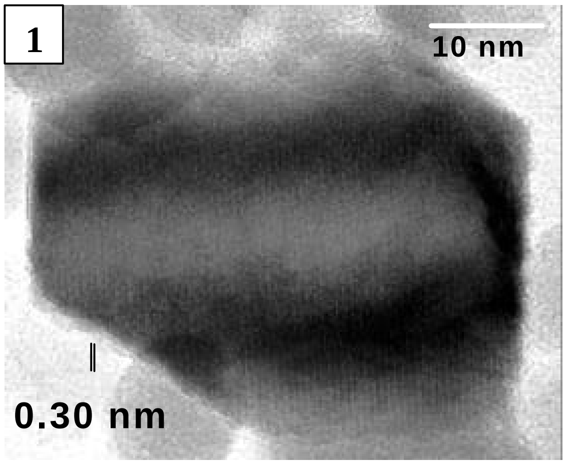
Methods Two ALH84001 chips containing carbonate globules were immersed in ~20 µl of 20% acetic acid at ~ 50 °C for 72 and 96 hours. Controls show that magnetite is not affected by this acid treatment. The residual chips were removed from the acid; the acid containing the magnetite was placed on carbon-coated TEM (transmission electron microscope) grids and allowed to evaporate. These grids were examined at 160 and 200 kV using a JEOL 2000 FX TEM equipped with a Link System IV energy dispersive x-ray spectrometer.

Results and Discussion Thousands of magnetite grains in clumps or groups were found on the TEM grids. The magnetite ranges from ~ 10-200 nm in size (in the longest dimension) and are composed only of Fe and O. Of the 526 magnetites documented, we have identified three distinct populations: **elongated prisms, whisker, and irregular**. Elongated prismatic magnetites comprise 27% of the population and are defined as moderately elongated (length/width<2.6) magnetites with rectangular projections having hexagonal cross-sections when viewed along the (111) axis (Figs. 1, 2). More than 99% of these magnetites have length/width or axial ratios between 1-2 (Fig. 3). Whisker magnetites, defined as having length/width ratios >3, comprised 6% of the total (Figs. 3, 4). We found two types of whisker magnetites (rounded ends with rounded cross-sections and whiskers that turn platy when viewed form another angle of rotation (Fig. 4)). Irregular magnetites (including cuboidal, tear drop, and generally irregular forms) made up 67% of the population. For comparison we performed similar analyses of magnetite crystals isolated from bacteria strain MV-1 and specific abiotic magnetite; we also compare these results to those described in the literature for abiotic magnetite [6,7]. The elongated prismatic magnetite particles in ALH84001 have high chemical purity, a restricted range of axial ratios, and distinct size distributions. Additionally, they have a unique morphology characterized by elongated growth along the (111) axis, a hexagonal cross section when viewed along that axis and a rectangular outline when viewed normal to the (111) axis (Figs. 1,2). These specific properties make them identical to magnetite crystals produced by specific extant terrestrial magnetotactic bacteria (Figs.5, 6; reference 8). These unique properties are not observed in any known natural inorganically-produced magnetite crystals. Inorganic magnetite particles we observed and those from the literature are nearly equidimensional (axial ratios ~1), and none observed or described from the literature have the elongated prismatic shapes and axial ratios of the elongated prismatic magnetites in ALH84001 and specific biogenic magnetite crystals (e.g. MV-1). Unless an inorganic analog for these crystals is found, the presence of elongated prismatic magnetite crystals in martian meteorite ALH84001 must be considered as likely evidence for primitive life on early Mars.

References: [1] McKay *et al.* (1996) *Science* **273**, 924. [2] Bazylinski and Moskowitz (1997) in Geomicrobiology: Interactions between Microbes and Minerals (Banfield and Nealson, eds.), 181. [3] Balkwill *et al* (1980) *J. Bacteriol*. **141**, 1399. [4] Bazylinski *et al* (1988) *Nature* **334**, 518. [5] Thornhill *et al*. (1994) *FEMS Microbiol. Lett*. **115**, 169. [6] Schwertmann and Cornell (1991) in Iron Oxides in the Laboratory: Preparation and Characterization, p.111. [7] Nanophase magnetite produced by Nanophase Technology at www.nanophase.com/TEXT/PRODUCTS/IronOxide.html [8] Sparks *et al*. (1990) *EPSL* **98**, 14.

Two views of a magnetite crystal from ALH84001 (left view displaying a hexagonal cross section at +17° and right view showing a hexagonal outline at –22°). Compare with Figs. 5, 6.

1



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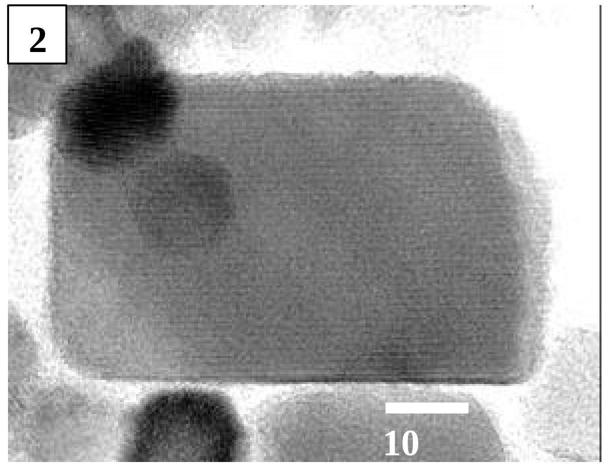

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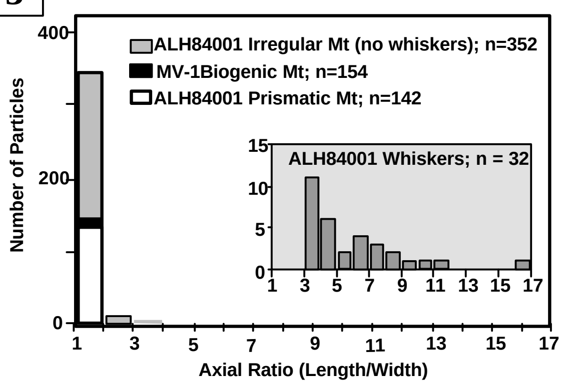

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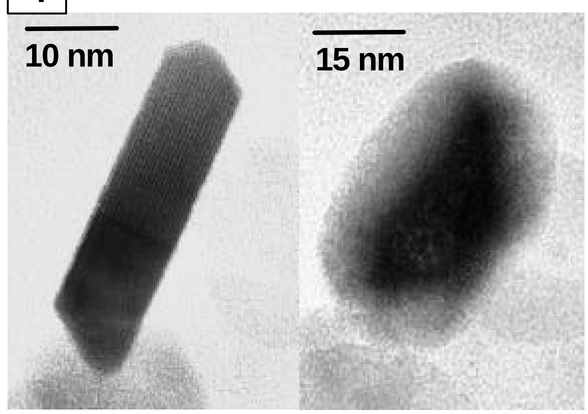

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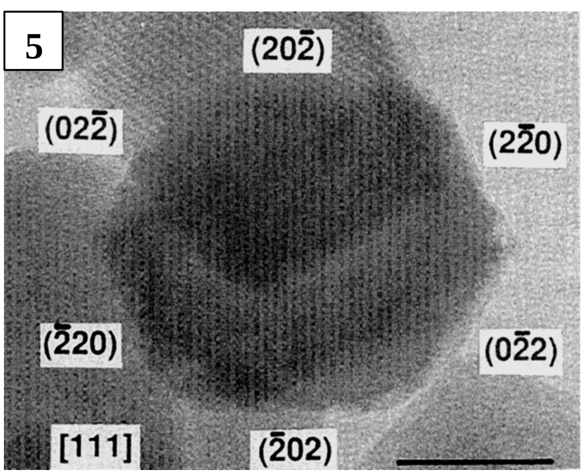

Two views of an elongated prismatic biogenic magnetite (from ref. 8); scale bar is 20 nm.

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